

# ULTRA-CLEAN TRANSPORTATION FUELS

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## INTRODUCTION

In the 21<sup>st</sup> century, there will be increasing national and global concern regarding energy utilization efficiency and environmental improvement. In the case of highway transportation, these concerns are especially compelling. A new generation of advanced fuels and fuel additives will be required to enable the emerging power systems of high-efficiency vehicles to achieve necessary increases in fuel efficiencies and dramatic decreases in emissions. Since petroleum-based fuels are expected to dominate the market for at least the next 30 years, practical considerations indicate that petroleum will be the primary feedstock. However, alternative, non-petroleum-based fuels must be developed as potential blending stocks and additives for petroleum-based fuels in the near term, and for 'neat fuels' in the long term. Coal must be considered as the most viable resource from which to generate these alternative fuels, blending stocks, and additives. To be successful, the development and commercialization of alternative, non-petroleum-based fuels will employ a "systems" approach, addressing fuels and engine/emissions-control technologies in the context of completely integrated vehicle power systems. The quest for the best societal solution will require that:

- advanced fuel-development activities address the complete spectrum of vehicle categories that are used in highway transportation; and,
- a long-term continuum of research and development (R&D) be conducted to influence and respond to the evolution of national energy efficiency goals, environmental policies and regulations.

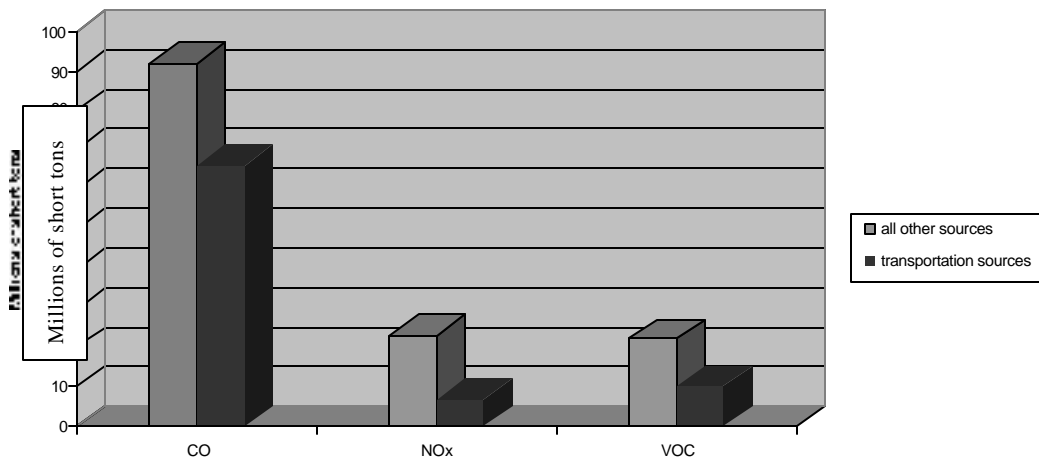
## CHALLENGES

It is recognized that a clean, stable and affordable energy supply for transportation is essential for sustaining economic growth, social stability, and public health. However, there are several major concerns facing transportation energy use, both domestically and worldwide. They include:

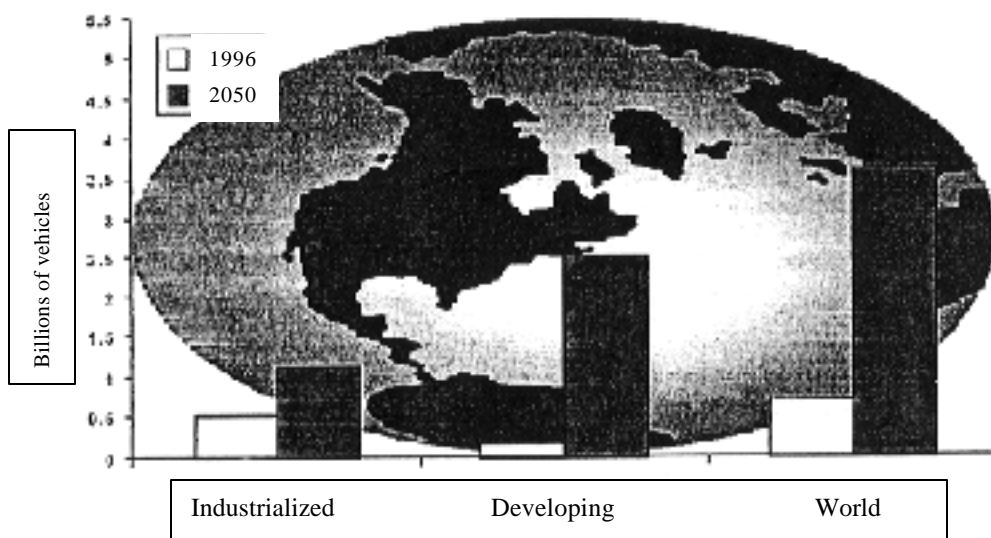
- potential health effects from regional and urban pollution resulting from transportation vehicle emissions, particularly ozone non-attainment and particulates;
- increasing emissions of the greenhouse gas carbon dioxide from rapidly expanding domestic and worldwide transportation sectors;
- energy security and the cost of oil imports as a result of continually increasing reliance on imported oil; and
- concern over the long-term availability of affordable liquid fuels from conventional petroleum, given the enormous expected worldwide expansion of transportation fuel demand in the next two decades.

### **Regional and Urban Pollution**

In the United States, transportation is responsible for 77% of the carbon monoxide, 49% of the nitrogen oxides and 40% of the volatile organic compounds in total manmade air emissions (Figure 1). All current forecasts project dramatic increases in vehicle numbers and mileage traveled, which will lead to greater transportation pollution unless significantly improved fuel-vehicle systems are developed and deployed (Figure 2). Currently, much effort from industry and government is directed towards improving fuel/vehicle systems. From this, it is clear that success in obtaining high efficiency and low emissions can only be achieved by simultaneously improving engines, exhaust after-treatments, and FUELS.



**Figure 1. Source: Transportation Energy Data Book, Edition 18, DOE/ORNL-6941 Sept 1998**



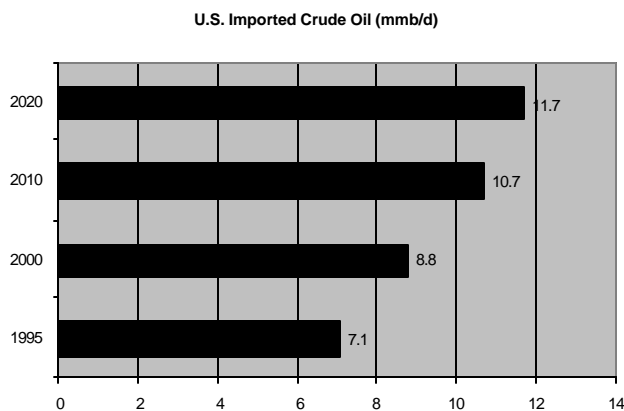
**Figure 2. Source: OTT Analytic Team**

### **Increasing Greenhouse Gas (GHG) Emissions from the Transportation Sector**

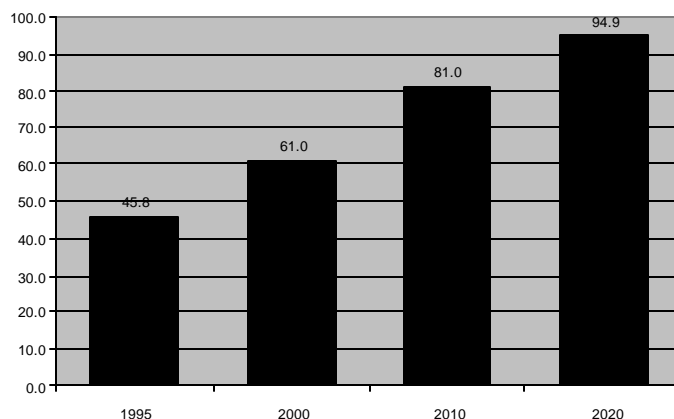
About one-third of carbon dioxide emissions in the U.S. from fossil energy use are produced by the transportation sector. Transportation accounts for approximately 470 million metric tons (mmt) out of a total carbon emissions of 1,460 mmt. Highway transportation accounts for 82% of total transportation emissions of carbon. The Energy Information Agency (EIA) projects that by 2020, total carbon emissions in the U.S. will increase to 1,960 mmt under business-as-usual assumptions, with transportation accounting for 690 mmt, or 35% of total U.S. carbon emissions.

### **Energy Security and the Increasing Costs of Imported Oil**

Currently, the U.S. imports 8.5 million-barrels-per-day (mmb/d) of crude oil and more than 2 mmb/d of finished products (Figure 3). The U.S. transportation sector now uses more oil than is produced domestically. At current world oil prices, the cost of crude oil imports is more than US\$70 billion; by 2020, the EIA estimates that this crude oil import bill will be about US\$100 billion (Figure 4). About 50% of this imported petroleum comes from OPEC countries, and since they are endowed with the bulk of the world's remaining oil, U.S. dependence on imported oil will increase in the future.



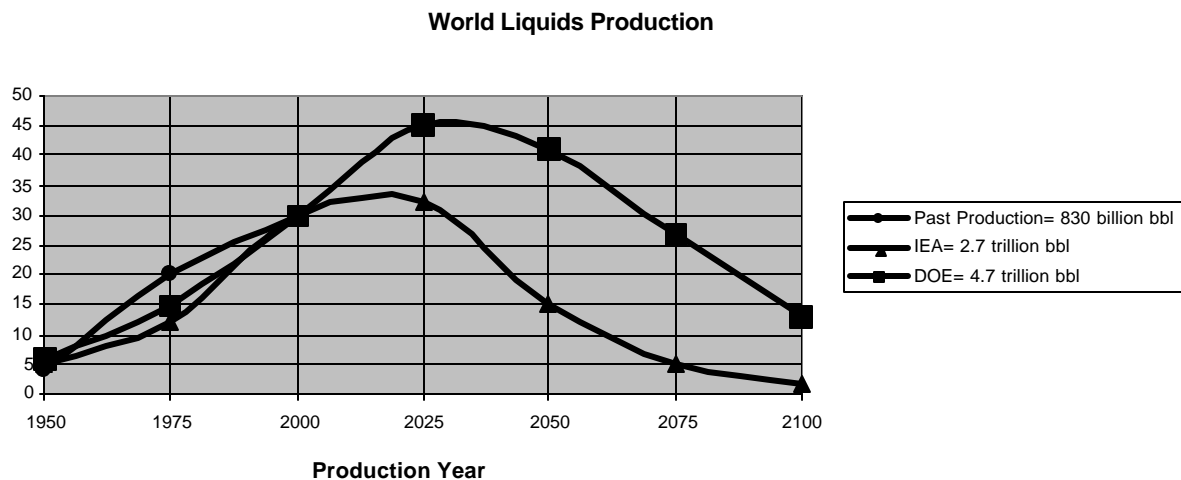
**Figure 3 (Source: EIA Annual Energy Outlook 1999)**



**Figure 4 (Source: EIA Annual Energy Outlook 1999)**

### **The Long-term Availability of Liquid Fuels from Petroleum**

Worldwide oil demand is expected to increase dramatically as vehicle registrations soar to unprecedented heights. However, conventional petroleum is a finite resource and its production will eventually peak and decline in the face of continually increasing demand (Figure 5). Because of uncertainties associated with estimating the volume of this resource, it is not known when this peak in production will occur. Based on current estimates of recoverable conventional oil (approximately 2.7 trillion barrels), and projected world oil demand, some experts predict that this peak will occur around 2015. The 1998 International Energy Agency (IEA) scenario presented at the G7 meeting in Moscow shows a peak in production around 2015. A recoverable resource consistent with the IEA estimate of oil production through 2020 would need to be 4.7 trillion barrels; this would require the volume of remaining oil to be double the current estimate. Around this peak in the world oil production curve, it is certain that the price of oil will rise significantly and permanently as conventional oil resources go into irreversible decline.



**Figure 5. Source: Oil and Gas Journal Feb 1, 1999**

### **VISION**

“Promote the development of future transportation systems that are highly efficient, ultra-clean and that minimize our dependency on imported oil, that have a minimum environmental impact and can be produced at an economically competitive cost.”

To realize this vision, the Ultra-Clean Transportation Fuels (UCTF) Program within the U.S. Department of Energy will foster the development and deployment of ultra-clean fuels to power these future transportation systems. These ultra-clean fuels will:

- be compatible with the existing liquid fuels transportation infrastructure;
- assist new and existing vehicle systems in meeting more stringent future emissions standards;
- enable the realization of highly efficient, advanced vehicle systems featuring significantly lower carbon dioxide emissions;

- be obtainable from both petroleum and non-petroleum sources;
- be candidate fuels for future advanced vehicle systems like hybrids and fuel cell vehicles, and,
- help strengthen the competitive position of the U.S. energy industry.

The benefits of realizing this vision can be quantified in a general manner by assuming the deployment of 1 mmb/d of these ultra-clean fuels. If high efficiency vehicle systems replaced current systems in this scenario, then the deployment of 1 mmb/d of these fuels could reduce carbon emissions from transportation by about 20 mmt of carbon per year. Further, it would reduce highway emissions of NO<sub>x</sub> by more than half a million tons per year, and carbon monoxide emissions by about 2 million tons per year. Costs for oil imports would be reduced by about US\$10 billion per year. Also, if this domestic 1 mmb/d industry produced the fuels from domestic natural gas and coal, it would generate more than 100,000 new jobs.

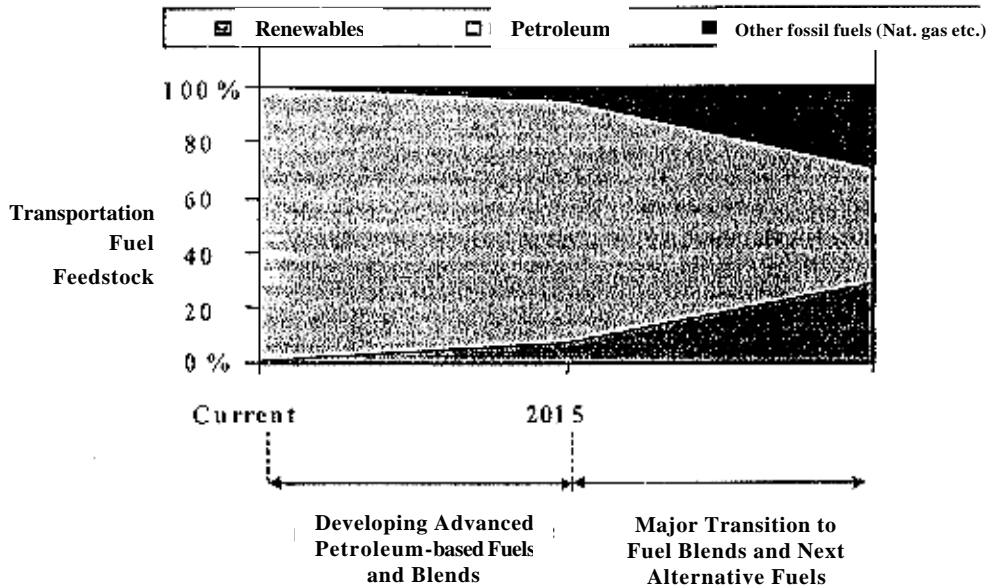
### **Strategy**

A critical role for the U.S. Department of Energy is to address global and domestic challenges while promoting the development of technologies that will provide the United States with a stable supply of clean and affordable transportation energy to fuel our economy in the 21<sup>st</sup> century. .

In order to fulfill this role in the most efficient and cost-effective manner, initiatives that have clean fuels development as their goal have been coordinated to form the comprehensive UCTF Program for producing fuels for ultra-low-emission vehicles (Figure 6). These activities reside in the coordination phase of the Petroleum Derived Fuels, Gas-to-Liquids, and Coal Transportation Fuels programs. This integrated activity promotes the production of ultra-clean fuels from conventional petroleum as well as other diverse resources. Integration makes more effective use of the skill mix, resources, and synergies among related programs.

**Figure 6. Ultra-clean Transportation Fuels Program**

The goal of the UCTF Program, in partnership with all elements of the refining and transportation industries, is to promote the development and deployment of technologies that will produce ultra-clean, high performance transportation fuels for the 21<sup>st</sup> century from both petroleum and non-petroleum sources (Figure 7). These will enable the introduction of advanced, highly efficient fuel/engine combinations. Promotion of fuel diversity will result in use of other feedstocks in addition to petroleum to produce ultra-clean fuels, thereby reducing U.S. dependence on imported petroleum. These ultra-clean liquid fuels will use the nation's existing transportation infrastructure.



**Figure 7.**

There are three R&D phases comprising this program, divided chronologically into near term, mid term and long term. Division of the program into three phases is designed to emphasize the principal objectives of each phase. Considerable overlap in R&D occurs among the phases, and advances in R&D during subsequent phases will largely be a result of building on prior efforts.

The principal near-term objective is to promote the efficient and cost-effective production of ultra-clean liquid transportation fuels that will help existing and new vehicle systems to meet future stringent vehicle emissions standards. This near-term phase of the program is designed to maximize the clean and efficient use of conventional petroleum by improving the yield and quality of transportation fuels from a barrel of crude. This can be done by improving processing of poor quality crudes, and by utilizing low-value products such as residua, petroleum coke, and other refinery waste products. Another major objective of this phase is to promote, by continued advanced research, production of ultra-clean fuels from other feedstocks including heavy oils, natural gas, coal and other carbonaceous feeds.

The principal mid-term objective is to promote the production of ultra-clean fuels, blending agents and fuel additives that can be used in advanced transportation systems like the Partnership for a New Generation of Motor Vehicles, Hybrids and Fuel cells. A key goal of the program is to encourage use of diverse feedstocks to produce fuels that

facilitate deployment of advanced high efficiency, low emissions transportation systems. This phase of the program is intended to maximize the clean and efficient use of all fossil resources (i.e. petroleum, natural gas, coal, and other carbonaceous feeds) for the production of ultra-clean fuels.

The principal long-term objective is to promote the identification, development, and commercialization of technologies necessary for the refining industry to produce sufficient quantities of ultra-clean fuels from domestic and imported fossil resources..

These ultra-clean fuels will be produced from a diversity of carbon-containing resources, and will be used in advanced transportation systems. These technologies will strengthen the competitiveness of the U.S. energy industry and assure the long-term availability of affordable liquid fuels for transportation. The program essentially is composed of two major elements: fuels development and fuels testing.

Fuel production activities focus on development and verification of the processing technologies needed to upgrade and convert all petroleum feedstocks to ultra-clean fuels. Other carbonaceous feeds like natural gas, petroleum cokes, refinery wastes, and coal will be used as feedstocks for developing ultra—fuel candidates like Fischer-Tropsch and others. Fuels development will produce advanced transportation fuels that will be tested in direct-injection engines fired by compression ignition and spark ignition. The combination of advanced fuel, engine, and emission controls will be optimized for maximum efficiency and minimal emissions.

## **GOVERNMENT RESPONSIBILITY**

Energy is critical to APEC economies' interests; therefore, it is appropriate for these economies to develop technologies that will provide a stable supplies of ultra-clean, affordable energy to fuel their transportation sectors in the 21<sup>st</sup> century. An affordable, stable supply of such fuels from domestic sources will help sustain economic growth, protect public health and welfare, improve competitiveness and maintain security. The government's role must be complementary to the role of the private sector and the limitations of federal dollars (Figure 8). Public/private partnerships and consortia are to be extensively utilized. Government clearly has a role in the following areas:

- 1) Improving the nation's environment by assisting the advancement of technologies to enable industry to more efficiently provide fuels that allow vehicle systems to meet future emission standards mandates;
- 2) Acting in the role(s) of coordinator/integrator/facilitator between refining and transportation industry groups and government to foster timely development and deployment of these ultra-clean fuels system;
- 3) Supporting near-term, mid-term, and long-term R&D that will provide fuels to: (1) improve the performance and lower the cost of existing fuels/vehicles systems, (2) be candidates for advanced systems like hybrids and fuel cells, and (3) allow diversification of the resource base to prolong the availability of liquid fuel resources; and
- 4) Coordinating and integrating efforts with other government programs.

## **SUMMARY**

The UCTF Program is fostering the development of advanced fuel production technologies that will accelerate deployment of highly efficient engine/vehicle systems. Its focus principally is on technologies that can produce ultra-clean liquid fuels that are

able to utilize the existing transportation fuels infrastructure. These ultra-clean fuels will be produced from a variety of resources including conventional and heavy crudes, bottom-of-the-barrel refinery products (residua and petroleum coke), natural gas, coal, biomass, and other carbonaceous feeds. Use of these fuels in conjunction with advanced engines and exhaust after-treatment systems will provide solutions to the principal challenges associated with global and domestic transportation.

The Program thus provides a comprehensive, integrated approach to the development of systems for the production and characterization of ultra-clean transportation fuels. These fuels will reduce regional and urban pollution, and permit the use of significantly higher efficiency automobiles, light trucks and sports vehicles, with the resulting reduction in greenhouse gas emissions, and reduced dependence on imported oil. The UCTF Program will, therefore, be the bridge to 21<sup>st</sup> century transportation systems.